Survey of the reptiles and amphibians of Yarrigan National Park in the Pilliga forest of northern inland New South Wales

Michael J. Murphy

NSW National Parks and Wildlife Service PO Box 105 Baradine NSW 2396

Email: michael.murphy@environment.nsw.gov.au

ABSTRACT

A survey of the herpetofauna of Yarrigan National Park (NP), in the southern Pilliga forest in northern inland New South Wales, was done over the period 2011 to 2013. The total identified herpetofauna community comprised 11 frog species (three families) and 35 reptiles (10 families) and includes a mix of eastern (Bassian), western (Eyrean) and northern (Torresian) species. This study demonstrates the significant species diversity, biogeographical interest and conservation value of the Pilliga forest's herpetofauna. Noteworthy findings from this study included a number of declining woodland reptile species (Nobbi *Diporiphora nobbi*, Australian Coral Snake *Brachyurophis australis* and Inland Carpet Python *Morelia spilota metcalfei*), locally rare species (Excitable Delma *Delma tincta* and Southern Rainbow Skink *Carlia tetradactyla*) and edge of range species (Litter Skink *Lygisaurus foliorum*). The study provides a useful benchmark of the composition and status of the herpetofauna community of Yarrigan NP in the first decade following a land management shift from timber production to conservation.

Key words: Herpetofauna community, temperate woodland, Pilliga forest, Brigalow Belt South bioregion, field survey methods.

DOI: http://dx.doi.org/10.7882/AZ.2016.030

Introduction

The temperate woodlands of southern inland Australia are among the continent's most severely impacted ecosystems, following the arrival of Europeans and the rapid development of modern agricultural landscapes. The original vegetation cover has been reduced to a fraction of its pre-European extent and much of what remains exists as scattered small fragments on less-productive soils unsuitable for agriculture (Margules and Pressey 2000; Benson 2008; Benson *et al.* 2010; Watson 2011). The Pilliga forest (30°25'-31°15'S, 148°40'-149°50'E), in Gamilaraay Aboriginal Country in the New South Wales (NSW) section of the Brigalow Belt South bioregion (northern inland NSW), is typical in occurring on poor sandy soils rejected for agriculture and surrounded by more productive farmland, but is unusual in its size. At about 450 000 ha, it is one of the largest surviving areas of woodland and open forest on the western inland slopes of eastern Australia's Great Dividing Range, and is a key area for biodiversity conservation in the NSW sheep-wheat belt (Date *et al.* 2002; Turbill and Ellis 2006; Murphy and Shea 2013; Murphy and Murphy 2015). The NSW government declared a suite of new conservation reserves in the Pilliga forest under the NSW *Brigalow and Nandewar Community Conservation Area Act 2005* in December 2005 as a major step in improving biodiversity conservation in the Brigalow Belt South bioregion.

The Pilliga forest comprises two landform units: an undulating terrain of low sandstone ridges and wide sandy valleys in the south-eastern part of the forest, and the apex of a compound alluvial outwash fan in the north and west (Murphy and Shea 2013). The primary aim of the present study was to describe the herpetofauna community of Yarrigan National Park (NP), one of the new conservation reserves situated in the south-east sandstone part of the Pilliga forest, and provide information to assist in the management of the reserve. A secondary aim was to examine the effectiveness of various herpetofauna survey techniques in the Pilliga forest.

The present study complements a recent study in Merriwindi State Conservation Area (SCA) (Murphy and Murphy 2015), which highlighted the significant biogeographical interest and conservation value of the herpetofauna of the Pilliga Outwash forests. The survey methods used in the two studies were identical and the survey effort was comparable (allowing for the greater size of Yarrigan NP). The format of the present paper follows Murphy and Murphy (2015) to facilitate comparison of the two studies. The results of the present study are also compared to broad-scale regional surveys (Date and Paull 2000; NSW NPWS 2000).

Study area and Methods

Yarrigan (also spelled Yarragin) NP (Figure 1 and Appendix 2) was formerly Yarrigan State Forest No. 272 and was managed primarily for timber production in accordance with the NSW *Forestry Act 1916* for approximately 90 years, before reservation as a national park in December 2005. Since that date it has been managed for conservation by the NSW National Parks and Wildlife Service (NPWS). The park is 3201 ha in area and is located 5 km south of Baradine and 27 km north-west of Coonabarabran. The park is situated on the terminus of a low ridge running north from the

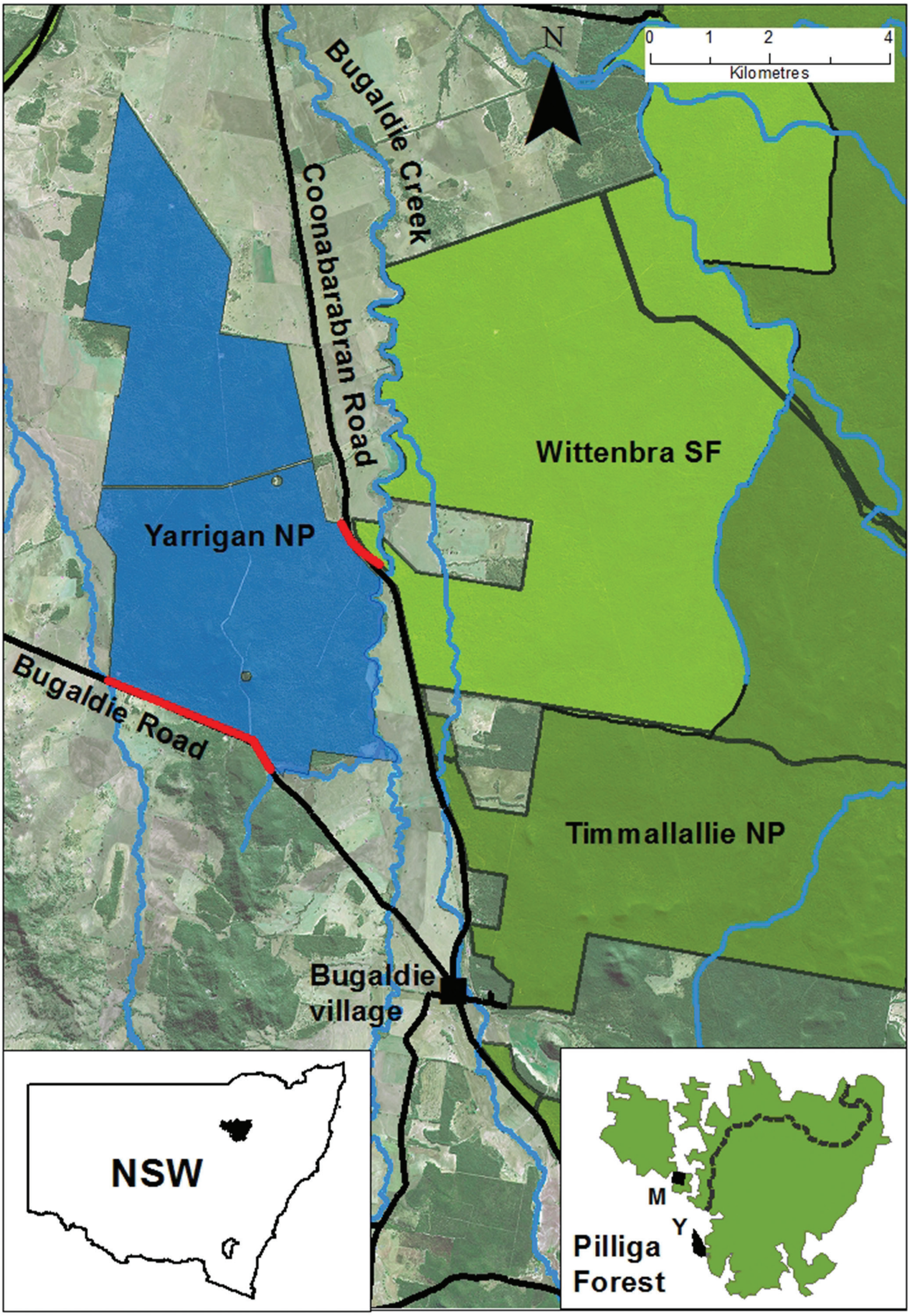


Figure 1. Location of Yarrigan NP. The inset map on the left shows the location of the Pilliga forest in northern inland NSW and the inset map on the right shows the context of Yarrigan NP (Y) and Merriwindi SCA (M) in the Pilliga forest. The dotted line marks the boundary between the south-eastern sandstone country and the outwash plain in the west and north. The main map shows Yarrigan NP, surrounding farmland and nearby forest areas. Sections of road adjacent to the park and included in the study area are marked in red. NP = national park, SF = state forest.

Warrumbungle Range and has a gently undulating terrain with an elevation ranging from 320-460 m (Australian Height Datum). The underlying geology of the park is predominantly sandstone of the Keelindi Beds formation (Jurassic-Cretaceous) but includes a small basalt-capped hilltop in the southern part of the park, an outlier of the nearby Warrumbungle Volcanic Complex (Miocene). The vegetation is dry open forest and woodland dominated by Narrow-leafed Ironbark *Eucalyptus crebra*, Pilliga Box *E. pilligaensis*, White Cypress Pine *Callitris glaucophylla* and Buloke *Allocasuarina luehmannii* with some Yellow Box *E. melliodora*, White Bloodwood *Corymbia trachyphloia* and River Oak *Casuarina cunninghamiana.* Timber harvesting in Yarrigan State Forest included commercial harvesting of *C. glaucophylla* for milling, felling of *E. crebra* for railway sleepers and cutting of various species for domestic firewood. The park was last logged in 2005. Surviving evidence of past forestry activities includes cut tree stumps, logging debris, log dumps and several small ground tanks and gravel pits. An ephemeral stream (Bugaldie Creek) runs along the south-eastern margin of the park and provides the only natural aquatic habitat, complemented by the ground tanks and gravel pits. A 1 km length of bitumen road bordering part of the park's eastern boundary and a 3 km length along the southern boundary were included in the study area (see Figure 1).

A field survey using a range of systematic and opportunistic methods (Table 1) was done in Yarrigan NP over the period April 2011 to May 2013. Survey methods requiring trapping were not employed because the volunteer nature of the study precluded regular visits. Voucher specimens and tissue samples of several species recorded were lodged in the collection of the Australian Museum (Sydney). Additional species which may potentially occur in Yarrigan NP were identified through assessment of local records and consideration of habitats available in the park. Records were obtained from unpublished reports, records of the author, the Office of Environment and Heritage Atlas of NSW Wildlife database and discussion with other NPWS staff. Nomenclature in this paper follows Cogger (2014).

Results

The field survey identified 11 frog species and 32 reptile species in Yarrigan NP. A record of one additional reptile species in 2011 shortly before the survey period was obtained from secondary sources and another two reptile species had been recorded in the park previously by the author. The total identified herpetofauna community of Yarrigan NP since 2006 therefore comprised 11 frog species representing six genera in three families and 35 reptile species representing 31 genera in 10 families. A complete list of species is provided in Table 2, together with information on the number of records from each survey method and microhabitats used. Information on voucher material collected is presented in Appendix 1 and examples of some of the species recorded are illustrated in Appendix 2.

Commonly recorded frogs in Yarrigan NP included *Litoria rubella*, *Litoria latopalmata* and *Limnodynastes tasmaniensis*. These three species comprised almost half (49%) of the total frog records collected. Common reptiles included *Heteronotia binoei*, *Oedura monilis*, *Morethia boulengeri* and *Egernia striolata*, with these four species comprising over half (54%) of the total reptile records. Rarely recorded species included *Crinia signifera*, *Pygopus lepidopodus*, *Carlia tetradactyla*, *Amphibolurus burnsi* and *Vermicella*

Table 1. Herpetofauna field survey methods employed in Yarrigan NP.

Survey method	Description	Survey effort	Timing
Timed active diurnal search for reptiles	Search of 2 ha area for minimum of 30 minutes looking for active animals and investigating potential shelter sites.	64 sites	September to May
Timed nocturnal search of water bodies for frogs	Search around margin of ground tank or ephemeral water body for minimum of 30 minutes looking for active animals and listening for calls.	33 searches	October to April
Nocturnal road searches for reptiles and frogs	Walking or driving along roads and management trails for minimum of 60 minutes looking for active animals.	22 nights	September to April
Placement of artificial shelter	Sheets of corrugated roofing iron placed on the ground and checked at intervals for any animals sheltering beneath.	4 sites (3-5 sheets per site). Total of 192 sheet-inspections	Throughout year
Opportunistic active diurnal search for reptiles and frogs.	Non-constrained searching for active animals and investigation of potential shelter sites. Included incidental observations of active animals while travelling between survey sites or undertaking other work in park as well as opportunistic active searching.	-	Throughout year
Opportunistic search for animals dead on roads.	Roads on southern (Bugaldie Road) and eastern (Coonabarabran Road) margins of reserve (see Fig. 1) regularly checked for animals killed by traffic.	-	Throughout year

Table 2. Frogs and reptiles recorded in Yarrigan NP 2011-2013 and additional species recorded by the author.

Survey method = number of records from each survey method. A = timed diurnal active search, B = timed nocturnal search of water bodies, C = nocturnal road search, D = artificial shelter, E = opportunistic diurnal observation, F = dead on road. Note numbers given are not number of individual animals. For systematic methods (A – D) = number of surveys when species recorded and for opportunistic methods (E and F) = number of records. **Microhabitat:** A = in crevice in anthropogenic structure, B = under loose bark on tree trunks, stumps and large logs, D = under large woody debris on ground, F = fossorial, G = active on ground surface, R = under loose rock, T = active on surface of tree trunks, major branches and fallen logs, U = under corrugated iron on ground, W = in or on margins of water bodies.

		Survey method							
Scientific name	Common name	A	B	C	D	E	F	Sum	Microhabitat
Limnodynastidae									
Limnodynastes dumerillii	Eastern Banjo Frog		1	2				**3**	GW
Limnodynastes tasmaniensis	Spotted Marsh Frog	1	15	2	1	4		**23**	GUW
Limnodynastes terraereginae	Northern Banjo Frog		11	7				**18**	GW
Neobatrachus sudelli	Common Spadefoot Toad		3	1				**4**	GW
Platyplectrum ornatum	Ornate Burrowing Frog		8	7		1		**16**	GW
Myobatrachidae									
Crinia signifera	Common Froglet					1		**1**	W
Uperoleia rugosa	Wrinkled Toadlet		10					**10**	W
Hylidae									
Litoria caerulea	Green Tree Frog	1	5	9		1	1	**17**	BGW
Litoria latopalmata	Broad-palmed Frog		23	3		2	1	**29**	DGW
Litoria peronii	Peron's Tree Frog		18	1				**19**	GW
Litoria rubella	Desert Tree Frog		19	12		2		**33**	AGW
Carphodactylidae									
Underwoodisaurus milii	Thick-tailed Gecko			1				**1**	G
Diplodactylidae									
Diplodactylus vittatus	Eastern Stone Gecko	1		9				**10**	GR
Oedura monilis	Ocellated Velvet Gecko	26		4				**30**	BG
Strophurus williamsi	Eastern Spiny-tailed Gecko	1		13				**14**	BG
Geckonnidae									
Gehyra dubia	Dubious Dtella	1		1		1		**3**	B
Gehyra variegata	Common Dtella	4		2				**6**	BG
Heteronotia binoei	Prickly Gecko	47		2	1			**50**	DGR
Pygopidae									
Delma tincta [1]	Excitable Delma							**-**	R
Lialis burtonis	Burton's Snake-lizard	1				1		**2**	G
Pygopus lepidopodus	Common Scaly-foot			1				**1**	G
Scincidae									
Anamalopus leuckartii	Two-clawed Worm-skink	6				1		**7**	FR
Carlia tetradactyla	Southern Rainbow Skink					1		**1**	G
Cryptoblepharus pannosus	Ragged Snake-eyed Skink	11				2		**13**	T
Ctenotus robustus	Striped Skink	1				2		**3**	BG
Egernia striolata	Tree Skink	24				2		**26**	ABT
Lerista punctatovittata	Eastern Robust Slider	11			1	1		**13**	DFU
Lerista timida	Timid Slider	10				1		**11**	D
Lygisaurus foliorum	Litter Skink	4			6			**10**	DGRU
Menetia greyii	Common Dwarf Skink	1						**1**	G
Morethia boulengeri	Boulenger's Skink	31		1	11			**43**	BDGTU
Tiliqua scincoides	Common Bluetongue					2		**2**	G
Agamidae									

Scientific name	Common name	Survey method A	B	C	D	E	F	Sum	Microhabitat
Amphibolurus burnsi [2]	Burn's Dragon							**-**	GT
Diporiphora nobbi	Nobbi					1		**1**	G
Pogona barbata	Eastern Bearded Dragon	1				1		**2**	G
Varanidae									
Varanus gouldii	Sand Goanna					4	1	**5**	G
Varanus varius	Lace Monitor	3				5	1	**9**	GT
Typhlopidae									
Ramphotyphlops bituberculatus	Blind Snake			1				**1**	G
Ramphotyphlops ligatus	Blind Snake	1						**1**	D
Boidae									
Morelia spilota metcalfei [3]	Inland Carpet Python							**-**	G
Elapidae									
Brachyurophis australis	Australian Coral Snake			1				**1**	G
Demansia psammophis	Yellow-faced Whipsnake					1		**1**	G
Furina diadema	Red-naped Snake	3						**3**	D
Pseudechis guttatus	Blue-bellied Black Snake					1	1	**2**	G
Pseudonaja textilis	Eastern Brown Snake						2	**2**	G
Vermicella annulata	Bandy-bandy			1				**1**	G

[1] Single Murphy record by active searching June 2007

[2] Two Murphy records by incidental diurnal observation October 2006 and February 2014

[3] Single incidental diurnal observation by NPWS staff February 2011 (W. Harvey and M. Cain NPWS pers. comm.)

annulata. Most frog species were found at both waterholes and along roads at night, with the exception of *Crinia signifera* (recorded calling by day from an inundated grassy area on the eastern edge of the park) and *Uperoleia rugosa* (recorded on the margins of waterholes at night). Multi-species simultaneous breeding aggregations of up to eight frog species were recorded at some waterhole sites. Key microhabitats for reptiles included bark cavities on tree trunks, stumps and large logs, large woody debris on the ground, and rock outcrops with crevices and loose rocks.

Information on the number of species recorded by each survey method and the number of species recorded by only one method is presented in Table 3. The most productive survey methods were diurnal active searches for reptiles, nocturnal road transects for frogs and reptiles and nocturnal searches of water bodies for frogs. As noted above, results from nocturnal searches of water bodies and along roads were largely overlapping with respect to the frog species recorded (90% overlap). In contrast, diurnal active searching and nocturnal road transects were largely complementary survey methods for reptiles, with only 28% overlap in the species recorded. Provision of artificial shelter sites and checking roads for dead animals identified relatively few species but were of value; the former providing the majority of records of *Lygisaurus foliorum* and the latter, the only records of *Pseudonaja textilis*. The cumulative curves for the three major systematic survey methods (Figure 2) suggest that most frogs in Yarrigan NP had probably been identified but that further survey effort was likely to identify additional reptiles. An additional 10 species (two frogs and eight reptiles) considered to potentially occur in the park, based on habitat suitability and local records, are listed in Table 4. One species, *Notaden bennettii*, was recorded by call on the eastern edge of Yarrigan NP in October 1993 (Atlas of NSW Wildlife 2015).

Table 3. Summary of survey results: number of species recorded by each method and number of species unique to that method.

Survey method & target group	No. species recorded	No. species recorded only by this method
Active diurnal search (systematic & opportunistic surveys combined) (reptiles)	6 frogs & 26 reptiles	1 frog & 14 reptiles
Timed nocturnal search of ground tanks and ephemeral water bodies (frogs)	10 frogs	1 frog
Nocturnal road searches (frogs & reptiles)	9 frogs & 12 reptiles	5 reptiles
Placement of artificial shelter (reptiles)	1 frog & 4 reptiles	nil
Opportunistic search for animals dead on roads (frogs & reptiles)	2 frogs & 4 reptiles	1 reptile

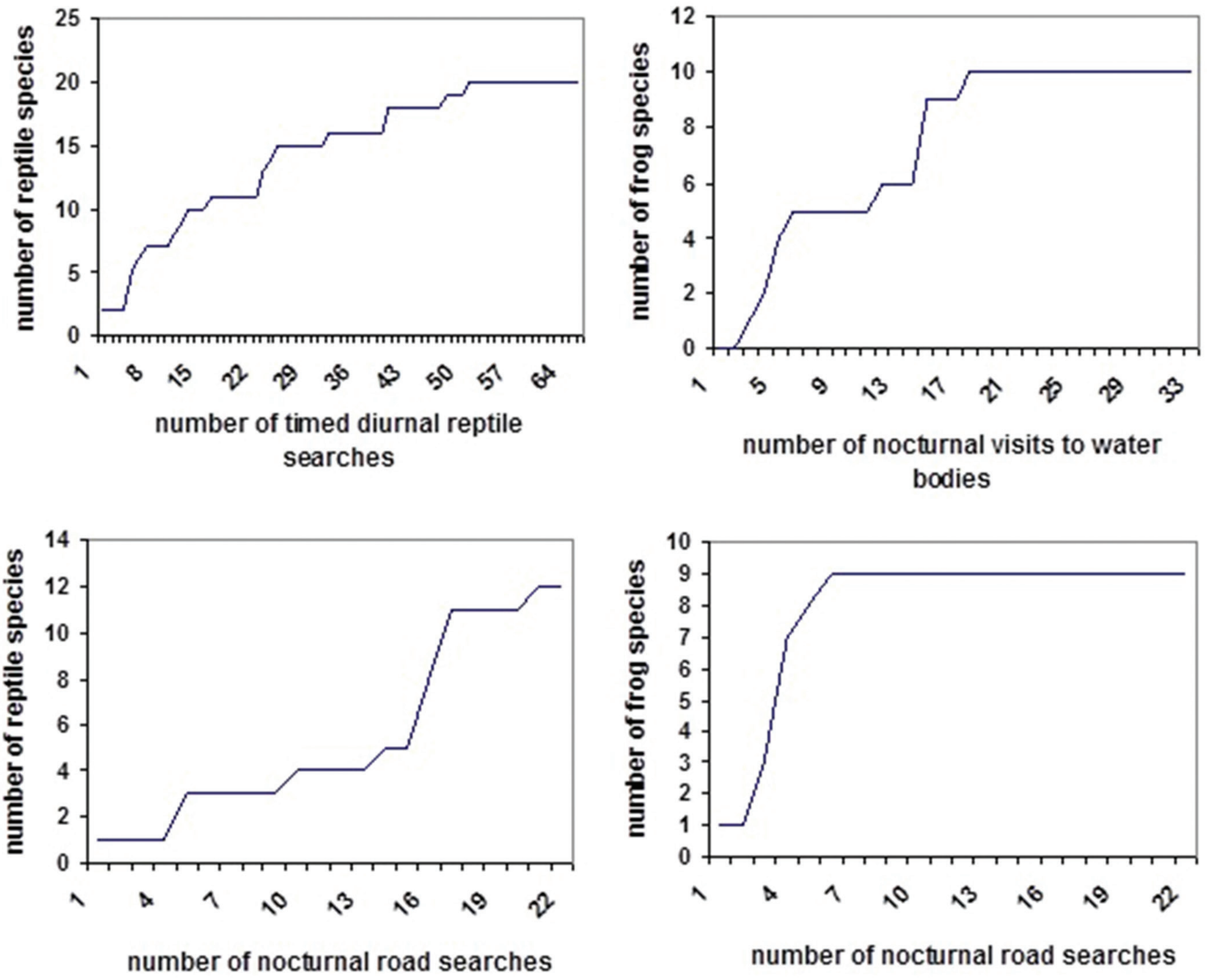


Figure 2. Cumulative species curves showing return for effort from timed diurnal active searching, nocturnal survey of water bodies and nocturnal road searches in Yarrigan NP 2011-2013.

Discussion

Biogeographic context

The rich herpetofauna community of Yarrigan NP and the broader Pilliga forest reflects its location in an overlap zone between eastern (Bassian), western (Eyrean) and northern (Torresian) faunal divisions. Such transitional areas typically have higher species diversities, resulting from overlapping faunal assemblages, and are considered of particular significance for conservation (Spector 2002, Murphy and Murphy 2011). The Bassian faunal component recorded in Yarrigan NP includes *Limnodynastes dumerillii*, *Crinia signifera*, *Diplodactylus vittatus*, *Pygopus lepidopodus* and *Varanus varius*. Eyrean species include *Neobatrachus sudelli*, *Uperoleia rugosa*, *Gehyra variegata* and *Lerista punctatovittata*, and Torresian species include *Platyplectrum ornatum*, *Lygisaurus foliorum*, *Amphibolurus burnsi* and *Ramphotyphlops ligatus*.

Comparison with Merriwindi survey

Comparison of the herpetofauna of Yarrigan NP with that of Merriwindi SCA, located only 20 km NNW on the flat outwash plain of the western Pilliga forest (see Figure 1), illustrates some of the local patterns of herpetofauna distribution within the Pilliga forest. A total of 39 species (14 frogs and 25 reptiles) were recorded in Merriwindi SCA (Murphy and Murphy 2015). Thirty species were shared with the present study, including several such as *Litoria rubella*, *L. latopalmata*, *Heteronotia binoei*, *Oedura monilis*, *Egernia striolata* and *Morethia boulengeri* which were among the most commonly recorded species in both reserves. Sixteen species recorded in Yarrigan NP were not detected in Merriwindi SCA. Some of the species only recorded in one reserve are considered likely to occur in both, on the basis of local records and habitat suitability (Murphy and Murphy 2015; this study), but notable differences in species assemblages remain. There were also quantitative differences in frequency of detection in some shared species. *Gehyra variegata*, for example, was recorded in 51% of systematic active diurnal searches and 36% of nocturnal road transects in Merriwindi SCA compared to 6% of diurnal searches and 9% of road transects in Yarrigan NP, while *Strophurus williamsi* was recorded in 7% of road transects in Merriwindi SCA compared to 59% in Yarrigan NP (Murphy and Murphy 2015; this study). In general, both reserves have a mix of Bassian, Eyrean and Torresian herpetofauna, but the Bassian influence in Yarrigan NP is comparatively stronger, with additional

Table 4. Additional species potentially occurring in Yarrigan NP.
(AA = Aboriginal Area, NR = Nature Reserve, SF = State Forest)

Scientific name	Common name	Local records (within 20 km)
Limnodynastidae		
Notaden bennettii	Crucifix Toad	Yarrigan NP Oct 1993 (Atlas of NSW Wildlife 2015) Yarrigan NP/Wittenbra SF 1993-1995 (Date and Paull 2000)
Myobatrachidae		
Pseudophryne bibronii	Brown Toadlet	Pilliga NR Apr 2003 (Atlas of NSW Wildlife 2015) Timmallallie NP May 2009 (Murphy record)
Chelidae		
Chelodina longicollis	Eastern Snake-necked Turtle	Coonabarabran Rd adjacent to Pilliga NR Oct 2007 (Murphy record) 2 km SSE of Bugaldie Mar 2011 (Murphy record) 3 km S of Baradine Nov 2015 (Murphy record)
Diplodactylidae		
Nebulifera robusta	Robust Velvet Gecko	Timmallallie NP Jun 1986 (Atlas of NSW Wildlife 2015) Ukerbarley AA Nov 2001 (Atlas of NSW Wildlife 2015)
Pygopodidae		
Pygopus schraederi	Eastern Hooded Scaly-foot	Baradine Nov 2010 (Murphy record)
Scincidae		
Ctenotus allotropis	Brown-blazed Ctenotus	Timmallallie NP 1993-1995 (Date and Paull 2000) Timmallallie NP Jan 2000 (Atlas of NSW Wildlife 2015) Timmallallie NP Mar 2007 (Murphy record)
Tiliqua rugosa	Shingleback	Coonabarabran Road adjacent to Ukerbarley AA Nov 2001 (Atlas of NSW Wildlife 2015)
Typhlopidae		
Ramphotyphlops wiedii	Blind Snake	Baradine Jan 2010 (Murphy record)
Elapidae		
Acanthophis antarcticus	Common Death Adder	Pilliga NR Dec 2006 (Murphy record) Yearinan 2011-2012 (D. Wurst NPWS pers. comm.)
Pseudechis porphyriacus	Red-bellied Black Snake	Baradine area May 2012 (Murphy record) Coonabarabran Road adjacent to Pilliga NR Jan 2015 (Murphy record)

Bassian species such as *Limnodynastes dumerillii*, *Crinia signifera* and *Pygopus lepidopodus* present and some Eyrean and Torresian species such as *Cyclorana platycephala* and *C. alboguttata* apparently absent.

The herpetofauna communities of Yarrigan NP and Merriwindi SCA are broadly representative of the sandstone forests of the south-east Pilliga and the outwash forests of the western Pilliga respectively. The combined list of 55 herpetofauna species (16 frogs and 39 reptiles) from the two reserves (Murphy and Murphy 2015; this study) comprises about 80% of the known herpetofauna species diversity of the entire Pilliga forest (Murphy unpublished data; Date and Paull 2000; NSW NPWS 2000). Most of the species not detected have only patchy distributions in the south-east Pilliga, such as *Pseudophryne bibronii*, *Ctenotus taeniolatus*, *Lerista bougainvillii* and *Liopholis whitii* (Murphy unpublished data; Atlas of NSW Wildlife 2015; Atlas of Living Australia 2015). The south-east Pilliga forest has greater habitat heterogeneity than the outwash forests, as a result of greater topographic variation, and not all herpetofauna habitats in this area are represented in Yarrigan NP.

Comparison with broad-scale regional surveys

Time and resources available for fauna inventory field surveys are always limited, and researchers seldom have the opportunity to study one area in detail. Regional-scale systematic fauna surveys can provide a valuable broad-scale overview but their results need to be interpreted with caution, as they are likely to under-estimate species richness at individual sites (Murphy and Murphy 2006). The present study in Yarrigan NP, and the Merriwindi SCA survey (Murphy and Murphy 2015), both had a relatively high survey effort for the size of the study areas. The results from these local-scale surveys with focussed survey effort can be compared to broader-scale surveys where the survey effort was necessarily spread over a greater area. Date and Paull (2000) surveyed the terrestrial vertebrate fauna at 41 forested sites on the NSW north-west slopes (primarily in the Brigalow Belt South bioregion), including 15 sites in the Pilliga forest, in 1993-1995 and recorded a total of 50 herpetofauna species in the Pilliga forest. One of their survey sites comprised the southern half of Yarrigan NP (then Yarrigan State Forest) and part of the adjacent Wittenbra State Forest, and 20 herpetofauna species were recorded here (Date and Paull 2000), less than half that recorded in the present study. NSW NPWS (2000) surveyed the terrestrial vertebrate fauna at 36 sites in the Pilliga forest and 18 sites in the Goonoo forest (near Dubbo) in 1999-2000 and recorded a total of 42 herpetofauna species in the Pilliga forest. Date and Paull (2000) and NSW NPWS (2000) both identified low returns from frog and reptile surveys as constraints of their surveys. Observations across the Pilliga forest over a 10 year period by the present author have identified a total of 68 herpetofauna species (Murphy unpublished data). The surveys in Yarrigan NP and Merriwindi SCA (this study; Murphy and Murphy 2015) recorded a combined total of 55 herpetofauna species. These two small reserves together comprise about 1% of the Pilliga forest (see Figure 1). The local-scale herpetofauna species richness identified in these two reserves is considered typical rather than unusual for the Pilliga forest (Murphy pers. obs.). Local-scale studies such as these can be valuable complements to broader regional-scale studies, providing insight into patterns of species richness and community complexity at a finer scale (Murphy 2012).

Survey effectiveness

The minimum suite of survey methods needed to record all 43 species identified in the 2011-2013 field survey in Yarrigan NP comprised five of the six methods, supporting the conclusion of previous studies concerning the value of employing a range of complementary methods in fauna inventory surveys (Parris *et al.* 1999; Swan and Foster 2005; Garden *et al.* 2007; Murphy and Murphy 2011; Murphy and Murphy 2015). The present study also highlighted the contribution of opportunistic (non-constrained) surveying as a dedicated component of the overall effort, which has previously been noted as being particularly valuable for reptile inventory surveys (Murphy and Murphy 2011).

Eleven of the species recorded in the 2011-2013 field survey (26% of the total) were represented by single records, higher than the 15% in the Merriwindi SCA herpetofauna survey (Murphy and Murphy 2015) and suggesting even more strongly that additional species present may have gone undetected. Another three reptile species are known from post-2006 records in Yarrigan NP and 10 species (two frogs and eight reptiles) known from the south-east sandstone area of the Pilliga forest within 20 km of Yarrigan NP were assessed as potential additional species. One of these, *Notaden bennettii*, was reported from the park in 1993 (Date and Paull 2000; Atlas of NSW Wildlife 2015). The cumulative species curves from the present survey (Figure 2) suggest that more reptile species in particular may have been detected with further survey effort.

Comparison of the cumulative species curves for reptiles between Yarrigan NP and Merriwindi SCA (Murphy and Murphy 2015; Figure 2 of this study) highlights some interesting observations regarding survey effectiveness. In the Merriwindi survey, the curve from timed diurnal active searches for reptiles leveled out relatively quickly (after about half of the survey effort of 45 sites), whereas in the Yarrigan survey the curve only started to flatten towards the end of the survey effort of 64 sites. This is likely to be a reflection of the higher habitat heterogeneity in Yarrigan NP compared to Merriwindi SCA (due to greater topographic variation), so that a greater number of random sites were needed to sample all habitats present. The nocturnal road transect method sampled multiple habitats simultaneously, and the general shape of the curves for reptiles from this method were very similar between the two reserves, apart from noting that optimal conditions for detection of reptiles active on roads at night (warm-hot weather after recent rain) occurred relatively later in the Yarrigan survey than at Merriwindi.

The cumulative species curves for frogs in the present survey (Figure 2) are broadly similar to those from the Merriwindi survey (Murphy and Murphy 2015). The present survey overlapped in part with the 2011-2012 *La Niña* event, which saw above-average rainfall across much of mainland Australia between October 2011 and March 2012 (Bureau of Meteorology 2015). This event had filled ground tanks and ephemeral water bodies in Yarrigan NP by late November 2011, triggering frog breeding activity, and its effect on detection of frogs can be seen in the species cumulative curves, where site 15 of the timed nocturnal searches of water bodies and site 4 of the timed nocturnal road searches both date from 26 November 2011. Several frog species, particularly burrowing species such as *Limnodynastes terraereginae*, *Neobatrachus sudelli* and *Platyplectrum ornatum*, would have been unlikely to be detected in Yarrigan NP if dry conditions had extended throughout the survey period.

Species of conservation significance

The rapid development of agricultural landscapes in inland southern Australia since European invasion has adversely impacted on the region's herpetofauna (Driscoll 2004; Brown *et al.* 2008; Wassens 2008). The Pilliga forest is one of the largest surviving woodland remnants on the inland western slopes of south-eastern Australia and provides a nationally significant refugium for woodland herpetofauna and other wildlife and a valuable benchmark for comparison with agricultural areas. The local context of Yarrigan NP as part of this much larger area of continuous forest is a factor in the high diversity of herpetofauna species found there, including species now rare in agricultural landscapes. Species from Yarrigan NP which have been identified as declining in the agricultural matrix and dependent on remnants of the original vegetation include *Diporiphora nobbi*, *Brachyurophis australis* and *Morelia spilota* (Shine 1994; Driscoll 2004).

Several additional species recorded in this study are considered locally significant either because of their rarity in the Pilliga forest or because they are at the edge of their range. The record of *Delma tincta* in Yarrigan NP is only the second documented record from the Pilliga forest (Atlas of NSW Wildlife 2015; Atlas of Living Australia 2015). Other nearby records include one from about 5 km south of Yarrigan NP in the Warrumbungle Range, and several from volcanic soils on the Liverpool Plains east of the Pilliga forest (Atlas of NSW Wildlife 2015; Atlas of Living Australia 2015). The Yarrigan record was on the basalt-capped hilltop (Murphy pers. obs.), and it is interesting to conjecture whether its occurrence in the park may be related to this geology. Areas of volcanic soil within the Pilliga forest are highly restricted (Murphy and Shea 2013).

Carlia tetradactyla occurs widely on the western slopes from southern Queensland to Victoria (Cogger 2014) but is considered rare in the NSW section of the Brigalow Belt South bioregion (NSW NPWS 2000). It has a limited distribution in the Pilliga forest, found only in relatively mesic areas on the southern margin of the forest (Murphy unpublished data; Atlas of NSW Wildlife 2015; Atlas of Living Australia 2015). The single Yarrigan record documented here was in a small dry swamp on the eastern edge of Yarrigan NP (Murphy pers. obs.) and represents a minor local range extension of about 10 km in the Pilliga forest (Atlas of NSW Wildlife 2015; Atlas of Living Australia 2015).

Lygisaurus foliorum is found along the coast and ranges of eastern Australia from north Queensland south to about Sydney (NSW) (Cogger 2014), and is at the western edge of its NSW range in the Brigalow Belt South bioregion (NSW NPWS 2000). The species is widespread in the eastern Pilliga forest with the records in Yarrigan NP documented in this study representing a minor local range extension of about 15 km (Murphy unpublished data; Atlas of NSW Wildlife 2015; Atlas of Living Australia 2015).

Management considerations

The diverse herpetofauna community of Yarrigan NP documented here is further evidence of the significant biodiversity conservation value of the Pilliga forest. Valuable habitat features for reptiles in Yarrigan NP include hollow-bearing trees, trees with loose bark, large woody debris and rock outcrops, while low-lying areas which temporarily fill with water after rain are valuable breeding sites for frogs. The mesic streamside open forest on the south-east margin of the park is significant in supporting *Carlia tetradactyla* and *Morelia spilota*. The rocky hilltop at Yarrigan fire tower where *Delma tincta* was recorded has additional biodiversity conservation values including an endemic narrow-range charopid land snail known only from this site (Murphy and Shea 2013) and its use as a major hill-topping site by a suite of butterfly species (Murphy unpublished data).

Driscoll (2004) found that most reptile species in an agricultural landscape in south-central NSW were confined to remnants of the original vegetation, including linear remnants along roadsides, and did not make use of the agricultural matrix. Of the 19 species recorded in Driscoll's (2004) study, only two individuals of a single species were recorded in open fields grazed by sheep and previously cropped. Yarrigan NP is largely surrounded by cleared agricultural land and is therefore at risk of isolation, but it does have two linkages to adjacent forested areas, one to the east to Wittenbra State Forest (part of the Pilliga forest) and another south along the ridge towards the Warrumbungle Range and Warrumbungle NP (see Figure 1). Both of the linkages are about 1 km wide; however, the habitat connectivity at both locations is reduced by intervening roads. The success of checking these roads for animals killed by traffic as a survey method in the present study highlights the risk they pose to movement by herpetofauna. The point where the eastern road (Coonabarabran Road) spans Bugaldie Creek by a bridge is the most valuable existing connection between Yarrigan NP and the rest of the Pilliga forest, being the only point where woodland-dependent herpetofauna can move between the park and adjacent forest areas without crossing a road.

The survival of a rich and significant herpetofauna in Yarrigan NP after approximately 90 years of use for timber production may seem surprising. It is likely that some disturbance-tolerant herpetofauna species are advantaged (at least temporarily) or neutrally affected by forestry activities, while disturbance-sensitive species with specific habitat preferences are disadvantaged (Kavanagh and Webb 1998; Lemckert 1999; Brown 2001; Newell and Goldingay 2004). While forestry management practices vary considerably from region to region, modern forestry prescriptions such as exclusion zones around riparian areas and rock outcrops and retention of hollow-bearing trees are typically measures aimed at protecting some habitat attributes for disturbance-sensitive species within logged forests. The present study was done only six to eight years following gazettal as a national park and a management shift from timber production to conservation. Changes in the current herpetofauna community may occur as the park slowly recovers from the disturbance associated with logging and returns to an old-growth forest structure. Parnaby *et al.* (2011) estimated that the replacement period for eucalypts with large hollows in the Pilliga forest was likely to exceed 250-400 years, so this process can be expected to be slow, reinforcing the importance of protecting existing hollow-bearing trees and recruitment trees.

Conclusions

This study demonstrates the significant species diversity, biogeographical interest and conservation value of the herpetofauna community of the sandstone forests of the south-east Pilliga. Comparison with a study in Merriwindi SCA (Murphy and Murphy 2015) provides insight into the similarities and differences with the herpetofauna of the outwash forests of the west and north Pilliga. The information documented here provides a useful benchmark of the composition and status of the herpetofauna community of Yarrigan NP in the first decade following a land management shift from timber production to conservation, and will be of value in future assessment of the herpetofauna community of Yarrigan NP and the broader Pilliga forest.

Acknowledgements

This project was done on a volunteer basis by the author under NPWS Scientific Licence number S10501 and Animal Research Authority number 071022/5. Thanks to Sue, Jess, Sam and Nicola Murphy, Ross Sadlier, Cecilie Beatson, Dave Wurst, Will Harvey, Mark Cain, Brad Law, Murray Ellis and an anonymous referee.

References

Atlas of Living Australia 2015. Available online at: http://www.ala.org.au. Accessed 15 November 2015.

Atlas of NSW Wildlife 2015. Available online at: http://www.bionet.nsw.gov.au. Accessed 15 November 2015.

Benson, J.S. 2008. New South Wales vegetation classification and assessment: Part 2 plant communities of the NSW south-western slopes bioregion and update of NSW Western Plains plant communities, version 2 of the NSWVCA project. *Cunninghamia* **10:** 599-673.

Benson, J.S., Richards, P.G., Waller, S. and Allen, C.B. 2010. New South Wales vegetation classification and assessment: Part 3 plant communities of the NSW Brigalow Belt South, Nandewar and west New England bioregions and update of NSW Western Plains and South-western Slopes plant communities, version 3 of the NSWVCA project. *Cunninghamia* **11:** 457-579.

Brown, G.W. 2001. The influence of habitat disturbance on reptiles in a box-ironbark eucalypt forest of south-eastern Australia. *Biodiversity and Conservation* **10:** 161-176.

Brown, G.W., Bennett, A.F. and Potts, J.M. 2008. Regional faunal decline – reptile occurrence in fragmented rural landscapes of south-eastern Australia. *Wildlife Research* **35:** 8-18. http://dx.doi.org/10.1071/WR07010

Bureau of Meteorology 2015. La Niña – detailed Australian analysis: La Niña 2010-2012. Available online at: http://www.bom.gov.au/climate/enso/lnlist/. Accessed 15 November 2015.

Cogger, H.G. 2014. Reptiles and Amphibians of Australia (7th edition). CSIRO Publishing: Collingwood, Victoria.

Date, E.M., Ford, H.A. and Recher, H.F. 2002. Impacts of logging, fire and grazing regimes on bird species assemblages of the Pilliga woodlands of New South Wales. *Pacific Conservation Biology* **8:** 177-195.

Date, E.M and Paull, D.C. 2000. Fauna Survey of the North-West Cypress/Ironbark Forests. State Forests of NSW, Dubbo, NSW.

Driscoll, D.A. 2004. Extinction and outbreaks accompany fragmentation of a reptile community. *Ecological Applications* **14:** 220-240. http://dx.doi.org/10.1890/02-5248

Garden, J.G., McAlpine, C.A., Possingham, H.P. and Jones, D.N. 2007. Using multiple survey methods to detect terrestrial reptiles and mammals: what are the most successful and cost-efficient combinations? *Wildlife Research* **34:** 218-227.

Kavanagh, R.P. and Webb, G.A. 1998. Effects of variable-intensity logging on mammals, reptiles and amphibians at Waratah Creek, southeastern New South Wales. *Pacific Conservation Biology* **4(4):** 326-347.

Lemckert, F.L. 1999. Impacts of selective logging on frogs in a forested area of northern New South Wales. *Biological Conservation* **89(3):** 321-328.

Margules, C.R. and Pressey, R.L. 2000. Systematic conservation planning. *Nature* **405:** 243-253.

Murphy, M.J. 2012. The vertebrate fauna of Currawananna State Forest and adjacent agricultural and aquatic habitats in the New South Wales south western slopes bioregion. *Australian Zoologist* 36(2): 209-228.

Murphy, M.J. and Murphy, J.K. 2015. Survey of the reptiles and amphibians of Merriwindi State Conservation Area in the Pilliga forest of northern inland New South Wales. *Australian Zoologist* **37(4):** 517-528. DOI: http://dx.doi.org/10.7882/AZ.2015.021

Murphy, M.J. and Murphy, S.P. 2006. Additions to the herpetofauna of The Rock Nature Reserve near Wagga Wagga, New South Wales. *Herpetofauna* 36(2): 99-101.

Murphy, M.J. and Murphy, S.P. 2011. A nine year survey of the vertebrate fauna of the Bruxner-Ulidarra conservation area in the New South Wales north coast bioregion. *Australian Zoologist* 35(3): 655-678.

Murphy, M.J. and Shea, M. 2013. Survey of the terrestrial and freshwater molluscan fauna of the Pilliga forest area in northern inland New South Wales, Australia. *Molluscan Research* 33(4): 237-253. http://dx.doi.org/10.1080/13235818.2013.801392.

New South Wales National Parks and Wildlife Service 2000. Brigalow Belt South Regional Assessment (Stage 1): Report on Preliminary Fauna Survey of Pilliga and Goonoo Forests, November 1999 to January 2000. Unpublished report by the NSW National Parks and Wildlife Service Western Directorate (Dubbo) for the Resource and Conservation Assessment Council.

Newell, D. and Goldingay, R. 2004. Conserving reptiles and frogs in the forests of New South Wales. Pp. 270-296 in the *Conservation of Australia's Forest Fauna* (second edition), edited by Daniel Lunney. Royal Zoological Society of New South Wales, Mosman, NSW, Australia.

Parnaby, H., Lunney, D. and Fleming, M. 2011. Four issues influencing the management of hollow-using bats of the Pilliga forests of inland New South Wales. Pp. 399-420 in *The Biology and Conservation of Australasian Bats*, edited by B. Law, P. Eby, D. Lunney and L. Lumsden. Royal Zoological Society of NSW, Mosman, NSW. http://dx.doi.org/10.7882/9780980327243

Parris, K.M., Norton, T.W. and Cunningham, R.B. 1999. A comparison of techniques for sampling amphibian communities in the forests of southeast Queensland, Australia. *Herpetologica* **55:** 271-83.

Shine, R. 1994. *The Biology and Management of the Diamond Python (*Morelia spilota spilota*) and Carpet Python (*Morelia spilota variegata*) in NSW*. NSW National Parks and Wildlife Service, Hurstville, NSW.

Spector, S. 2002. Biogeographic crossroads as priority areas for biodiversity conservation. *Conservation Biology* **16:** 1480-1487.

Swan, G. and Foster, R. 2005. The reptiles and amphibians of Mutawintji National Park, western New South Wales. *Australian Zoologist* **33(1):** 39-48.

Turbill, C. and Ellis, M. 2006. Distribution and abundance of the south-eastern form of the greater long-eared bat *Nyctophilus timoriensis*. *Australian Mammalogy* **28(1):** 1-6. doi: 10.1071/AM06001

Wassens, S. 2008. Review of the past distribution and decline of the southern bell frog *Litoria raniformis* in New South Wales. *Australian Zoologist* **34(3):** 446-452.

Watson, D.M. 2011. A productivity-based explanation for woodland bird declines: poorer soils yield less food. *Emu* **111:** 10-18.

APPENDIX 1

Voucher specimens and tissue samples collected from Yarrigan NP during this study and lodged in the Australian Museum, Sydney.

Limnodynastes terraereginae R175780; *Uperoleia rugosa* R175772; *Litoria caerulea* R175781; *Heteronotia binoei* R175789; *Gehyra dubia* R175783, R175790; *Gehyra variegata* R175791; *Strophurus williamsi* R175769, R175773; *Anamolopus leuckartii* R175775, R175777; *Lerista timida* R175770, R175776 + tissue sample EBU No. 57221; *Lygisaurus foliorum* R175774, R175784, R175798; *Cryptoblepharus pannosus* R175771, R175779, R175782, R175786 + tissue sample EBU No. 57223, R175787, R175792; *Egernia striolata* R175778 + tissue sample EBU No. 57222, R175788 + tissue sample EBU No. 57224; *Menetia greyii* R175797; *Ramphotyphlops bituberculatus* R.178206; *Ramphotyphlops ligatus* R175793; *Pseudonaja textilis* R.178207, R.178212.

APPENDIX 2

Narrow-leafed Ironbark-White Cypress Pine-Bulloke open forest in Yarrigan NP. This is the most widespread vegetation community in the park. Photo: M.J. Murphy.

Pilliga Box-White Cypress Pine woodland in Yarrigan NP, showing a typical park road used for nocturnal road transects in this study. Photo: M.J. Murphy.

The Ornate Burrowing Frog *Platyplectrum ornatum* (photographed at Yarrigan) is part of the northern (Torresian) component of Yarrigan's herpetofauna community. This burrowing species was detected when La Niña conditions triggered frog breeding activity. Photo: M.J. Murphy.

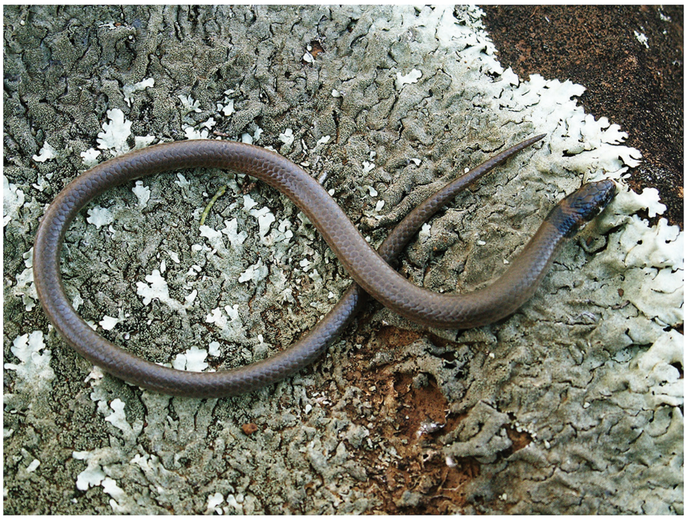
APPENDIX 2

The Desert Tree Frog *Litoria rubella* (photographed at Yarrigan), another species with a Torresian distribution, was the most frequently recorded frog species in Yarrigan NP. Photo: M.J. Murphy.

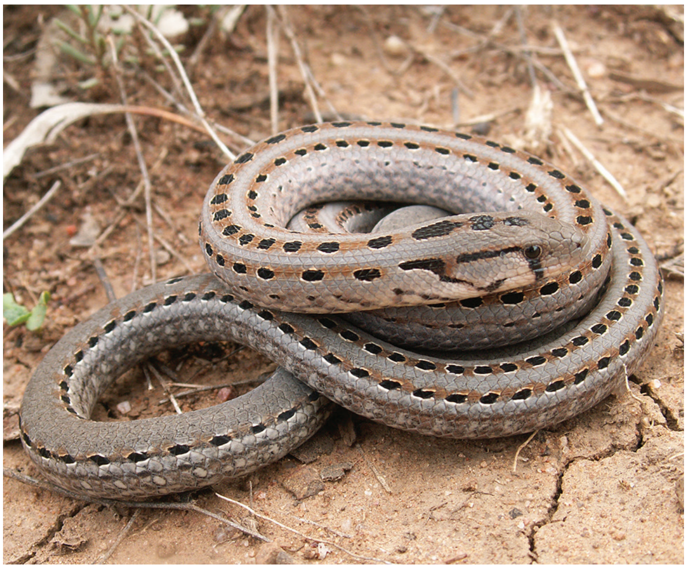
The large and strikingly patterned Thick-tailed Gecko *Underwoodisaurus milii* (photographed at Yarrigan) was part of a diverse gecko fauna of seven species found in Yarrigan NP. Photo: M.J. Murphy.

The Prickly Gecko *Heteronotia binoei* (photographed at Yarrigan), part of the western (Eyrean) component of Yarrigan's herpetofauna, was the most frequently recorded gecko in Yarrigan NP and is the most commonly seen gecko in the Pilliga forest. Photo: M.J. Murphy.

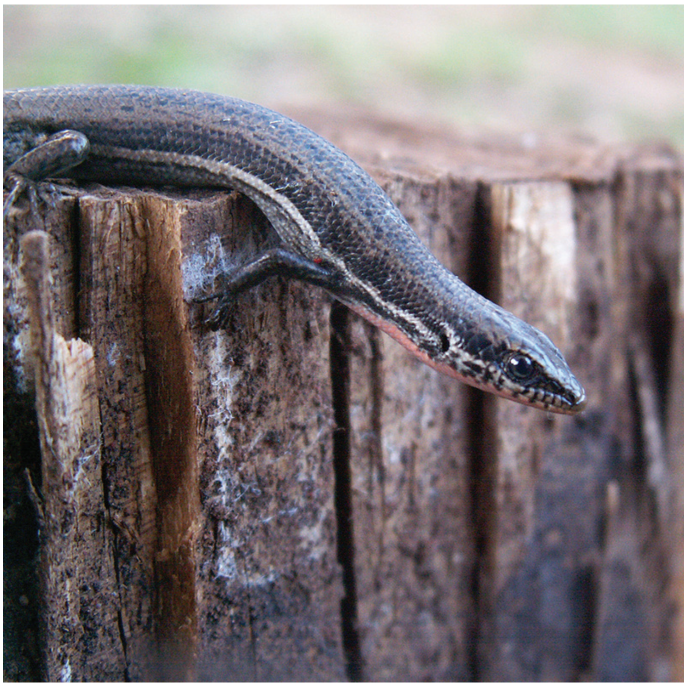
APPENDIX 2



The Excitable Delma *Delma tincta* (photographed at Yarrigan) is a rare species in the Pilliga forest, with the record on a basalt-capped hill in Yarrigan NP documented here being one of very few local records. Photo: M.J. Murphy.



The Common Scaly-foot *Pygopus lepidopodus* (photographed at Yarrigan) is part of the eastern (Bassian) component of Yarrigan's herpetofauna community. Photo: M.J. Murphy.



Boulenger's Skink *Morethia boulengeri* (photographed at Yarrigan), another western (Eyrean) species, is the commonest skink species in the Pilliga forest, and was the most frequently recorded skink in Yarrigan NP. Photo: M.J. Murphy.

APPENDIX 2

The Common Bluetongue *Tiliqua scincoides* (photographed at Yarrigan), a large skink familiar to urban dwellers, is typically only infrequently observed in native forest and woodland and was rarely recorded in Yarrigan NP. Photo: M.J. Murphy.

A Red-naped Snake *Furina diadema* (photographed at Yarrigan) found sheltering by day under debris. Active diurnal searching was the most productive survey method for reptiles in this study. Photo: M.J. Murphy.

A large Blue-bellied Black Snake *Pseudechis guttatus* (photographed at Yarrigan) found basking in June. Large elapid snakes generally occur at low densities and are often under-represented in general fauna surveys. Photo: M.J. Murphy.